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Albert M. Day, Director

Special Scientific Report No. 41

DDT INVESTIGATIONS BY THE FISH AND WILDLIFE SERVICE IN 1946

By

Arnold L. Nelson and Eugene W. Surber

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Explanatory Note

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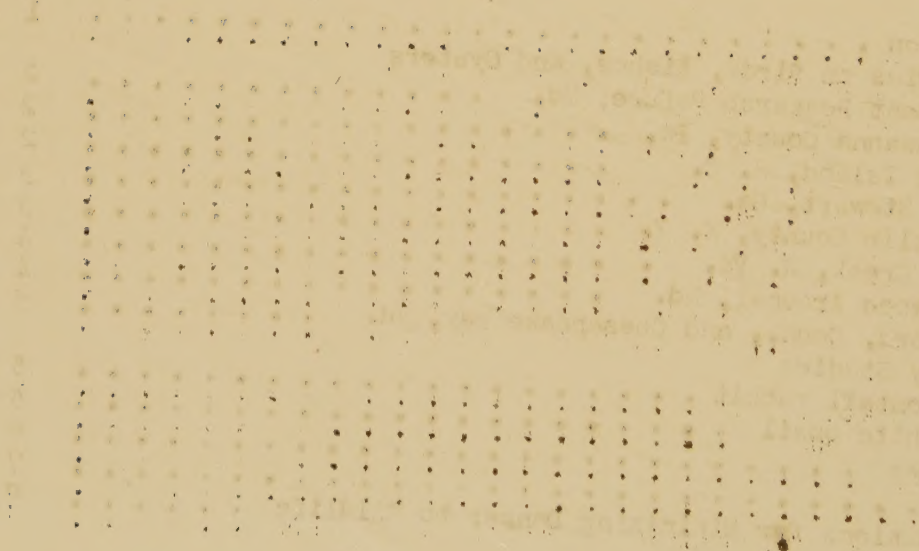

INTRODUCTION

World War II brought DDT into use as an important insecticide. From the control of pests of man and domestic animals its usefulness soon expanded to include control of harmful field crop, orchard, truck, and forest insects. Investigations of possible dangers and of increased usefulness paralleled each other from the first.

As soon as DDT was taken outdoors the dangers were instantly multiplied. In 1945 the Fish and Wildlife Service and the Bureau of Entomology and Plant Quarantine of the United States Department of Agriculture carried on extensive cooperative investigations on the effects on fishes and wildlife of DDT used for killing mosquitoes and for controlling gypsy moth, spruce budworm and other harmful forest insects. Both field and laboratory studies were made, and the results were summarized early in 1946 in Fish and Wildlife Service Circular 11, entitled "DDT: its effect on fish and wildlife." Six of these studies were described in detail in the July 1946 number of The Journal of Wildlife Management.

The 1945 Investigations on the use of DDT for insect control and on the effects of such use on fish and wildlife led to the conclusion that the lowest dosages needed to effectively control mosquitoes and forest insects would kill little wildlife. It was found that crustaceans, fishes, and amphibians were more susceptible to DDT poisoning than were birds and mammals. The goal of the year's work was the development of recommendations for the use of DDT in such ways as to minimize danger to wildlife. These recommendations formed the most important part of the printed circular.

In 1946 the program of research comprised routine follow-ups on 1945 studies and the extension of others in which conclusive data had not been obtained. Some new studies were also conducted. The Bureau of Entomology and Plant Quarantine cooperated in the planning of each of these investigations and worked with the Fish and Wildlife Service on several, particularly those on fishes. On other studies the Fish and Wildlife Service was assisted by the National Audubon Society, the New York State Conservation Department, the United States Army, and the United States Public Health Service.

As in 1945, most of the DDT used in field studies was sprayed by airplane at rates varying from 1/5 to 5 pounds per acre. The rates were under 1.1 pound per acre in the majority of the areas; and the majority of the applications were in oil. In one area four applications of DDT were made at weekly intervals; in another two applications with a four-weeks' interval. All of the other areas received a single application. Weather conditions and forest canopies of different density caused considerable variation in the amount of DDT that reached the ground. Spectrophotometric analyses were made from deposits on over fifty filter paper samples in each of two areas. The amounts averaged one-fifth the rate of application in one area and one-seventh in the other. At no station did the amount deposited on the ground approach the amount sprayed above the canopy.

Investigations on two areas, Patuxent Research Refuge, Maryland, and Lackawanna County, Pennsylvania, were continuations of work on birds begun in 1945. The other areas were new; and the principal work was on birds, fishes, and oysters. Laboratory studies were made at the Fish and Wildlife Service's Patuxent Research Refuge, Laurel, Maryland (post office formerly Bowie, Md.) to determine the effects of sub-lethal doses of DDT on quail reproduction, as well as other effects on quail and cottontail rabbits; and at its Fishery Station at Leetown, West Virginia on the toxicity of DDT to fishes.

Results of the 1946 investigations confirm the conclusions of the preceding year with regard to the susceptibility of birds and fishes to DDT poisoning under field conditions. It is apparent that much still remains to be done before the long-time effects of DDT on wildlife can be evaluated.

A summary of the individual studies follows:

FIELD STUDIES ON BIRDS, FISHES, AND OYSTERS

Patuxent Research Refuge, Md.

On June 8, 1946 the 117-acre tract of bottomland forest that was treated with DDT in 1945 was sprayed again by airplane with an oil solution of DDT at the rate of 1.1 pounds per acre. Nineteen bird census trips were made by Chandler S. Robbins, who censused the same 31-acre study area in 1945. The period of observation extended from before until well after the time of spraying. None of the few changes in the bird population following the application was attributable to DDT.

Lackawanna County, Pa.

Breeding bird censuses were taken in June 1946 by Richard H. Pough of the National Audubon Society on the three forested areas that were studied in 1945. The 1945 control area was sprayed by airplane on April 18, 1946 with DDT in oil at the rate of 1 pound of toxicant per acre. The purpose was to determine the effects on the gypsy moth and on birds of an application of DDT made before trees came into leaf and before the arrival of most of the birds. This area was found to have a bird population similar to that in 1945. The 1946 population of the census area that received 1 pound of DDT per acre in 1945 also was similar to the populations before and after the 1945 spraying. The population of the census area that received 5 pounds of DDT per acre in 1945 was about 85 per cent that of the 1945 pre-spray population. Species composition of this area had changed to include a greater proportion of scarlet tanagers and other birds characteristic of more mature forest. Singing scarlet tanagers, redstarts, and Blackburnian warblers were mostly young males, which indicated the probability of heavy mortality in these species in 1945.

Bulls Island, S. C.

In late April, 1946 a solution of DDT in oil was applied by airplane to six, mostly forested, study areas on Bulls Island, Charleston County, S. C.

The amount applied was 2 pounds per acre and 3 pounds per acre. Five species of ticks were the objects of control. Three pounds of DDT per acre reduced their numbers drastically. Insect numbers also were much reduced. On a single plot that was sprayed from the ground with 1 pound of DDT per acre ticks were nearly eliminated.

Over fifty filter paper disks were distributed through the forest before it was sprayed from the air. Spectrophotometric analyses indicated an average deposition of 0.14 pound per acre of DDT, and a maximum deposition of 0.91 pound.

Birds were censused by W. P. Baldwin, Phil Goodrum, and John W. Aldrich on 64 acres of dense forest sprayed at the rate of 3 pounds of DDT per acre, and on a 64-acre control area. There was no change in bird populations attributable to DDT.

General observations were made on other vertebrates. Amphibians were commonly killed but many were unaffected. Reptiles and fishes were affected less than amphibians; mammals apparently not at all.

A three-acre tract of high salt marsh was included within a plot that received 2 pounds of DDT per acre. This treatment killed nearly all of 4 species of fiddler crabs, but scarcely affected two species of snails and one of mussel.

Camp Stewart, Ga.

Populations on two pine forest areas at Camp Stewart, Liberty County, Ga., were determined by John W. Aldrich and Thomas D. Burleigh between April 2 and May 6, 1946. An area of 57 acres was sprayed by airplane with an oil solution of DDT four times at weekly intervals, each time at the rate of 1 pound of DDT per acre. The applications were made to determine general effects on insects and wildlife. An area of 48 acres served as a control.

Over fifty filter paper disks were distributed through the first area before it was sprayed on each of two dates. The amount of DDT deposited was analyzed spectrophotometrically; it was found to average 0.201 pound per acre, with a maximum deposition of 0.58 pound.

Insect numbers were conspicuously reduced following each application, but were back again within a week. Birds did not appear to be affected.

Franklin County, N. Y.

Between June 3 and August 6, 1946 John L. George and Robert T. Mitchell studied the effects of feeding DDT-treated insects to nestling birds near Lake Clear Junction, N. Y. In this vicinity DDT was applied by airplane, blower, and hand sprayer in an oil solution at the rate of 1 pound per acre for the experimental control of spruce budworm.

Twenty-four nests were studied, the nestlings being fed at the age of 3 or 4 days on spruce budworm larvae killed by the application of DDT to the forest or by cornborer larvae and pupae killed in the laboratory by a DDT spray. Control nestlings were fed uncontaminated larvae.

Nestlings in 10 nests were given a portion of their food in the form of DDT-treated larvae. The nestlings were weighed daily. One nestling in each nest was fed uncontaminated larvae. In 8 nests the nestlings were fed approximately 25 per cent of their body weight each day, the parents providing additional food. In 2 nests they were fed approximately 50 per cent of their body weight each day. In each of these 2 nests a single nestling was left to be fed solely by its parents. No sign of DDT poisoning appeared in any of these nestlings.

A laboratory study was made of 14 nests located outside the DDT sprayed areas. One nestling in each was left to be fed by its parents and was undisturbed except for daily weighings. A second nestling from each nest was fed uncontaminated food at the laboratory. The other nestlings were fed DDT killed or sprayed insects for three days in the laboratory: as much as they could each for the first two days, 25 per cent of their weight on the third. Surviving nestlings were returned to their nests and were left undisturbed except for daily weighings. Of 27 subjects studied in the laboratory DDT was the direct cause of the death of 7 and apparently contributed to the death of 8 others.

Back Creek, W. Va.

A study was made by Clarence H. Hoffmann and Eugene W. Surber in late July 1946 of the effect on fish and aquatic insects of an aerial application of wettable DDT at the rate of 1 pound per acre. The DDT was applied to a 0.9-mile section of Back Creek, a smallmouth bass stream in Berkeley County. DDT analyzed spectrophotometrically from approximately 50 samples, indicated an average deposition of 0.39 pound of DDT per acre.

Of the many minnows in the stream only a few were affected. A total of 61 native fish were found dead. Practically all were fish hatched during the year. The heaviest losses of native fish occurred on the third and fourth days after spraying, but dead fish were found until the seventh day. This seemed to be due to the delayed toxic effect of wettable DDT.

Live boxes, stocked with warm water fishes, were placed above, within and below the sprayed area. Ten per cent of these fishes were lost from all causes.

Samples of insects from the bottoms of riffles showed a survival of about 30 per cent of the insects originally present at the lower stations.

Edgewood Arsenal, Md.

On July 16, 1946 2500 acres of this post in Harford County, Md., were sprayed by airplane with an oil solution of DDT at the rate of 0.2 pound of DDT per acre. On August 14 the area was sprayed again; this time at the rate of 0.26 pound per acre. Mosquito control was the object.

Observations on fishes and wildlife on a portion of the sprayed area were made by Eugene W. Surber, William H. Stickel, and David Young. An abundant fish population in a marsh-bound, vegetation-filled bay was moderately affected following the first application, slightly following the second. No dead fish could be found on August 19, five days after the second application. No other affected vertebrates were found at any time.

Milford, Conn. and Chesapeake Bay, Md.

During 1946 investigations were made at Milford, Conn., by Victor L. Loosanoff and in Chesapeake Bay by James B. Engle on the effect of treating with DDT oyster shells used for catching spat. DDT applied in an oil solution and in an emulsion in concentrations varying from 1 to 5 pounds of DDT per acre did not inhibit oyster setting. It was effective against barnacles, but much less so against other fouling organisms.

LABORATORY STUDIES

Cottontail rabbit

At the Patuxent Research Refuge, Md., Don R. Coburn and E. Ediger subjected each of two lots of five adult cottontails to applications of DDT in an oil spray, on a pastureland type of habitat, at rates of 5 and 7-1/2 pounds per acre, respectively. All of the animals died after having lost an average of 9.1 ounces in weight. Typical clinical symptoms of DDT poisoning were observed, and all losses occurred within a period of 9 days. No control animals died; their loss in weight averaged 0.8 ounce.

Bobwhite quail

Bobwhite quail were used by Don R. Coburn and E. Ediger in two experiments at the Patuxent Research Refuge, Md. The purpose of the first was to determine the effect on reproduction of the feeding of sub-lethal doses of DDT to insectivorous birds. Eleven pairs each on two levels of medication and ten pairs without medication, as controls, were carried through one breeding season. Percentages of DDT fed in the mash diets were 0.013 and 0.008. These represented, respectively, 1/2 and 1/4 of the amount found lethal in 1945 for 50 per cent of the 5-weeks-old birds fed for a period of 63 days. Daily food consumption in the present experiment averaged 15 grams per bird. Records were kept of changes in weight, egg production, fertility, hatchability, and livability of chicks. The only significant variation from the control group of birds, at either level of medication, was in a shortening of the laying period by 28 days in the case of the birds on the higher level. Histopathological studies showed degenerative changes in the liver and kidneys. These were less marked at the lower level of medication. Representative breeding pairs of the original birds and of birds raised from them will be used during the 1947 breeding season to determine any residual or transmitted effects.

The purpose of the second experiment was to determine the effect on growing birds of external contact with DDT alone, and of external contact combined with the feeding of 0.01 per cent of DDT in the diet. Ten 12-weeks-old quail were used in each of several pens placed directly on the ground without the

benefit of false bottoms. Some of the pens with their birds, were sprayed with DDT in oil at the rates of 1 and 5 pounds per acre. The other pens were sprayed in the same manner except that the birds were kept in their hovers out of contact with the spray. During the 69-day test period four applications of DDT were made. The pens were moved once; the entire DDT-covered vegetation was eaten in each location. No clinical evidence of DDT poisoning was apparent. Tissue preparations, which may show degenerative change in this experiment are not completed and must await evaluation. Representative pairs of birds were selected from each group for the determination of possible effects on their reproductive function during the next breeding season.

Fishes

At the Leetown, W. Va., Fishery Station several experiments were carried on in aquaria and in ponds by Eugene W. Surber of the Fish and Wildlife Service and C. H. Hoffman of the Bureau of Entomology and Plant Quarantine, with the assistance of Edward P. Merkel and Dorothy D. Friddle.

In one aquarium study DDT was applied both as an oil spray and in suspension at the rates of 0.25 and 0.5 pound per acre. The mortality of bluegills was 100 per cent at both concentrations. Other species were less susceptible. In another experiment brook, brown, and rainbow trout were placed in a series of aquaria that contained some mud, and in another series without mud. DDT was applied in a suspension at the rate of 0.25 pound per acre. In the aquaria with mud, mortality varied from zero in brook trout to 39 per cent in rainbow trout; while in those without mud it ranged from 84 to 100 per cent. Of the three species rainbow trout were affected most.

On August 12, 1 pound per acre of DDT was applied in a suspension to four connected raceways supplied with hard spring water. They were stocked with brook trout, rainbow trout, smallmouth bass, and golden shiners, between 3 and 4 inches in length. Trout appeared not to be particularly sensitive to DDT under these conditions.

In October six concrete daphnia ponds were stocked with fingerlings of several species. Two of these were used as controls and four were sprayed with DDT in a suspension at the rate of 1 pound per acre. Regular hatchery trout diet was fed and no running water was permitted. Nearly all of the black crappies, smallmouth bass, and bluegill sunfish were seriously affected, while golden shiners, rainbow trout, and largemouth bass were affected relatively little.

In November the same six daphnia ponds were restocked with 2-inch bluegill sunfish and 3-3/4 inch rainbow trout. Again two ponds were used as controls and four were sprayed with DDT in a suspension at the rate of 1 pound per acre. Five per cent of the trout were lost in three fed ponds, one of which was not sprayed; while 45 per cent died in the unfed ponds. Sunfish losses, were 12 per cent in the fed ponds, 25 per cent in the unfed ponds.

Nine dirt-bottomed ponds were stocked with advanced fry of largemouth and smallmouth bass in June. There was ample natural food. Three ponds were sprayed with a suspension at the rate of 0.37, 0.50, and 1.0 pound of DDT per

acre. A 0.5 pound per acre oil spray was applied to three ponds. Three ponds were untreated and served as controls. After a lapse of 12 days the ponds were drained. In the control ponds 88 per cent of the bass were recovered. There was no survival in the ponds treated with DDT in suspension, nor in two of those treated with an oil spray. In the third pond sprayed with DDT in oil there was a 12 per cent survival of each species.

A similar experiment in July dealt with 100 fingerlings each of black crappie, bluegill and brown bullhead in nine ponds, three of which were sprayed with DDT in suspension at the rate of 0.5 pound per acre and three with DDT in oil at the rates of 0.37, 0.50, and 1.0 pound per acre. Mortality in the ponds treated with the oil solution of DDT was 61 per cent or more; in those treated with a suspension it ranged from 8 per cent to 78 per cent.

In August nine dirt-bottomed ponds were again stocked with a variety of fishes. Three were treated with an oil solution and three with a suspension, each containing DDT at the rate of 1 pound per acre. Both forms were about equally destructive.

SUMMARY

In 1946, investigations of DDT damage to fish and wildlife were continued in two areas where observations were made in 1945 and were extended to new localities in six different states. Fair to successful control of ticks, insects, and barnacles was effected.

DDT was applied in most instances by airplane, as an oil spray, at rates under 1.1 pound per acre. The maximum rate in the field was 5 pounds per acre. A single application was the rule in all but two areas. In one of these there were four at weekly intervals, in the other there were two with a four-weeks' interval. Spectrophotometric analyses in two areas indicated that only a small fraction of the DDT distributed was deposited on the ground.

Mortality to adult mammals and birds was not apparent where DDT was applied in concentrations up to 3 pounds per acre, but a mortality of at least 25 per cent occurred in a group of nestlings fed in a laboratory with insects killed with a 1-pound-per-acre concentration of DDT applied as a spray. Amphibians were affected by an application at the rate of 3 pounds per acre. Nearly all of a fiddler crab population was killed by 2 pounds of DDT per acre. Oysters were practically uninjured, while barnacle growth was inhibited by concentrations up to 5 pounds per acre.

In the laboratory all of a group of adult cottontail rabbits died in a habitat sprayed with DDT in oil at the rate of 5 pounds per acre. Sublethal doses of DDT administered with food resulted in a shortening of the laying period in bobwhite quail; but young bobwhite quail in a habitat sprayed with DDT in oil at the rate of 5 pounds per acre and at the same ti e fed sublethal doses of DDT showed no clinical evidence of DDT poisoning.

In laboratory and hatchery pond experiments, varying susceptibility of different species of fishes to DDT poisoning was indicated; although under similar conditions smallmouth bass were one time less, another time more, affected than were largemouth bass.

DDT in suspension killed about as many fish as did DDT in oil, at the same concentration.

For some species, under some conditions, mortality was high at concentrations of DDT as low as 0.25 pound per acre. Mortality was less in aquaria containing some mud than in those without, apparently due to inactivation of DDT by the mud. It was less in ponds where the fish were fed than in those where they were not fed: therefore, the physical condition of the fish appeared to be a factor in their survival.

Young fish were more susceptible to DDT poisoning than were adults.

RECOMMENDATIONS FOR MINIMIZING DANGER TO WILDLIFE

The recommendations made in Circular 11 still hold. They are as follows:

Use DDT for the control of an insect pest only after weighing the value of such control against the harm that will be done to beneficial forms of life. Wherever more than a small area is involved, consult county agricultural agents, State or Federal entomologists, wildlife and fishery biologists, and United States Public Health Service officials.

Use one-fifth pound or less of DDT per acre in an oil solution to avoid damage to fishes, crabs, or crayfishes; use less than 2 pounds per acre to avoid damage to birds, amphibians, and mammals in forest areas. Because of its greater effectiveness, use smaller quantities of DDT in emulsions.

Use DDT only where it is needed. Wherever it is applied by airplane, provide careful plane-to-ground control to insure even coverage and to prevent local overdosage.

In forest-pest control, wherever feasible, leave strips untreated at the first application to serve as undistrubed sanctuaries for wildlife, treating these strips at a later time or in succeeding seasons if necessary.

In the control of early appearing insect pests, apply DDT, if possible, just before the emergence of leaves and the main spring migration of birds; for late appearing pests, delay applications, whenever practicable, past the nesting period of birds. Adjust crop applications and mosquito-control applications so far as possible to avoid the nesting period.

Because of the sensitivity of fishes and crabs to DDT, avoid as far as possible direct applications to streams, lakes, and coastal bays.

Wherever DDT is used, make careful before and after observations of mammals, birds, fishes, and other wildlife.